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Information Processing as a Key Factor for Modern Federations of Combat Information Systems

Dr. Stefan Krusche, Dr. Andreas Tolk
 Industrianlagenbetriebsgesellschaft mbH
 Einsteinstr. 20
 85521 Ottobrunn
 Germany

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Summary

Building flexible collaborations of different heterogeneous military units just in time is one of the key factors to perform joint and combined operations successfully. It is one of the most important prerequisites to and challenges for information systems to support these collaborations with user-adapted information to the warfighter where it is needed.

For information systems, this is a requirement to adequately build federations of different and heterogeneous data and information sources on the basis of the existing data bases. This objective is only achieved by a new approach towards information sharing based on data mediation techniques which enable the configuration for different information systems towards a global information source to support military business processes across systems, nations and unit borders.

One of the key factors for data mediation techniques is, that it is not an isolated technical solution to gain interoperability between different information systems, but is integrated in an overall data management process, which produces standard business objects for data exchange and standard mediation rules to configure the technical solution. In NATO, this process already has started in form of respective NATO Data Administration Group (NDAG) activities, that aims at the development of standardized data elements.

Data Mediation means to establish federations of heterogeneous data sources on the basis of a common data exchange format while the data and systems itself are kept where and as they are. In other words, on the basis of the data administration and management processes the integration of legacy systems becomes possible without having to change the systems itself. This paper provides an overview of this new integration technique and its relation to already ongoing NATO activities.

Introduction

After catchwords like Enterprise Resource Planning (ERP), Supply Chain Management (SCM), and Customer Relationship Management (CRM), the free market of E-Commerce is actually looking at a new category of software strategy, the so called Collaborative Product Commerce (CPC) [Aberdeen, 1999]. Basic idea is, that

instead of the old make-to-stock production model the market is demanding more and more new build-to-demand models. Instead of long planing and introducing procedures, the products are built by tying together the multitude of heterogeneous and geographically dispersed computing systems. This results in faster-to-the-market products that can be influenced during the production process by direct interaction with the customer. Thus, it is possible to innovate with products the customer wants and needs, and of which the respective sources can be delivered.

The technologies that are making CPC possible have been developed over just the last two years. A key attribute of CPC is a loosely coupled integration of data and application functionality, i.e., a common shared data model that does not rely on data commonality for individuals to collaborate. In other words, the information is shared using a common "language" that is not closely tied to one of the participating computer systems or applications.

The Aberdeen Group forecasts great benefits for partners using CPC. It is seen as a key methodology for gaining the best out of the opportunities of the Internet technology.

On the first look, this seems to be a strange introduction for a paper dealing with future Command, Control, Consultation, and Intelligence Systems (C3IS). What does Command and Control have in common with the E-Commerce methodologies and the CPC?

In the eyes of the authors, there are not only commonalities between C3IS and CPC. Obviously, there is a paradigm shift in systems development going on affecting also C3I systems. Componentware and middleware solutions enables the system developer for the first time to build systems coupling reusable components using standardized integration platforms by vertical component integration. Respective management processes insure the alignments of architecture and the semantic consistency of the interchange data. To summarize this, systems development becomes mainly integration of applications delivering the necessary functionality.

Already today, modern C3I systems are comprising increasingly commercial off the shelf products (COTS),

thus, it has to be taken into account what are the main integration strategies of the commercial sector.

In addition, when looking at the operational requirements in military joint and combined operations (including operations other than war – OOTW), the answer to the question of commonalities is as follows:

- **Military Requirement:** The requirements for C3IS are changing rapidly, nearly from operation to operation. The warfighter needs a system that meets his actual needs on time. In addition, the systems must be deliverable in short periods.

CPC: Innovating with products customers want and sourcing can deliver.

- **Military Requirement:** The requirements have to be brought into the production circle as fast as possible. Many requirements become obvious not before the first actions within an operation. This is especially true for OOTW. Thus, a close connection between the warfighter and the supplier is necessary.

CPC: Customers can directly interact with the system and the product developers having access to the different prototypes within an evolutionary software development loop.

- **Military Requirement:** All allies and partners from different countries with different systems have to work together interoperable in order to reach the common goal. It will not be likely that everyone is using the same system for “command and control” in a broad sense (e.g., in common operations with the Red Cross, etc.). In addition, Command and Control Systems as well as Consultation Systems may have to stay in the supporting home nation and are not available in the operation area.

CPC: Tying together the multitude of heterogeneous and geographically dispersed computing systems used today to create, build, and service a product without requiring the enterprise to scrap those systems and start new.

- **Military Requirement:** The systems have to be delivered fast without great additional costs.

CPC: Faster time to market solutions.

This list should make obvious that the solutions of CPC can be of tremendous benefit to meet the requirements of modern federations of Combat Information Systems. The key technologies that are making CPC possible are available to C3I system developers also:

- High-speed, reliable, secure communications,
- Browser-based, standardized User Interfaces,

- Java or other object-oriented technologies enabling the implementation of reusable components,
- URL-style location transparency,
- Secure portals,
- Server and storage high-end scalability,
- Business functions (applications) delivered as services on demand.

This paper describes how Collaborative Information Processing as a Key Factor for Modern Federations of Combat Information Systems can be made reality for the next generation of C3I systems and how legacy systems can be migrated into this new world.

Data Modeling and Shared Data Models

The CPC is mainly based on a common understanding of the data to be interchanged between the participating systems. In order to benefit from the ideas, a common shared data model for military applications for actual and future operations is needed. Fortunately, a lot of work has been done on this field already that is ready to be implemented.

As pointed out in [Krusche and Tolk, 1999], generally each organization in the domain of defense depends on access to information in order to perform its mission. It must create and maintain certain information that is essential to its assigned tasks. Some of this information is private, of no interest to any other organization.

Most organizations, however, produce information that must be shared with others, e.g., operation plans, location and activity of a given unit, information on the logistics, etc. This information must be made available, in a controlled manner, to any authorized user who needs access to it.

At present, almost every defense information infrastructure exists as a collection of heterogeneous, non-integrated systems. This is also true for C3I systems, and – when trying to bring them together in common joint combined operations – the problem of interconnections even increases. This is due to the fact that each organization builds systems to meet its own information requirements, with little concern for satisfying the requirements of others, or of considering in advance the need for information exchange.

If any information exchange takes place, however, as a rule this information exchange is based on *ad hoc* interfaces. The result is an extremely rigid information infrastructure that costs months and millions to be changed or extended, and, which cannot cope with the increasing demand for widely integrated data sharing between multiple mission-related applications and systems. Actual solutions cannot solve these problems, thus, new ways have to be found in the era of joint and combined operations.

The Shared Data Environment (SHADE) fully described in [DoD, 1996] is a strategy to promote command and control systems' interoperability through a global view on the data of the battlespace, which is made available, in a controlled manner, to any authorized user who needs access to it. The objective is to define a *global infosphere*, that supplies a fused, real-time, true representation of the battlespace, to allow for an integrated data sharing between multiple mission-related applications and systems. The SHADE's technical focus and priorities are driven by near term systems' integration, migration and interoperability requirements that are identified in the Defense Information Infrastructure (DII) Common Operational Environment (COE) context. The main conceptual features of the SHADE address data interoperability for federations of system components and systems in general, not restricted to C3I systems.

Within SHADE, standard data elements (SDE) are defined for information exchange. In order to be able to manage this SDEs, a common shared data model is needed comprising all SDEs and giving them a semantic context.

A data model being able to cope with the requirements for the common shared data model has to have the following qualities:

- It must capture the information requirements of a wide range of battlefield functional areas. A common shared data model is best characterized as a "to-be" model of the required battlefield information rather than a model that is constructed with direct reference to existing current needs for information exchange.
- For flexible integration of future information (exchange) requirements, the data model must be constructed in a way that future information elements simply extend the model while its existing structure remains unchanged.

As has been shown in several publications, e.g., [Krusche and Tolk, 1999; Tolk, 1999], the ATCCIS Generic Hub [NATO, 1996] meets both requirements quite well, as it has been designed to meet exactly these requirements by data modeling experts of almost all nations in NATO during the last 10 years.

As has been pointed out, the definition of standard data elements (SDE) required for information exchange, the coordination and control of their implementation and use within systems have to be the central objectives of an overall data management organization. They may not longer be under the responsibility of system managers who's legal and understandable objective is to optimize their system and, logically, neglecting often the requirements of the superimposed federation of systems.

In general, data management is planning, organizing and managing of data by defining and using rules, methods, tools and respective resources to identify, clarify, define

and standardize the meaning of data as of their relations. This results in validated standard data elements and relations, which are going to be represented and distributed as a common shared data model.

The overall objective to be reached by introducing a data management is, to coordinate and to control the numerous system projects technically and organizationally, in order to improve the integrity, quality, security and availability of standard data elements. Due to this objective, the following central tasks of the data management organization are proposed:

- Definition of standard data elements across system boundaries,
- Evolutionary development of a common shared data model as a reference representation for standard data elements,
- Representation of standard data elements through a common shared data model,
- Definition of rules and methods for
 - access, modification and distribution of standard data elements,
 - introduction of new information exchange requirements,
 - Coordination and Control of system projects using the standard data elements in order to assure their consistent use and interpretation within different applications and systems.

To summarize, in order to reach the objective of a common shared data model comprising the standard data elements of the application domain, a common data management organization is essential.

A Framework for Collaborative Information Processing

After having agreed on a common shared data model and the mapping rules for harmonization defined and distributed by the system independent data management organization, data mediation in the sense of automatic translation of system's data into standardized data elements and vice versa becomes possible. Thus, in order to achieve a collaborative information processing based of a common understanding of the data to be interchanged, the key factor is a data management agency, which is responsible for harmonizing legacy data models with the respective common shared data model and the validation and accreditation of the harmonization results.

When using an appropriate toolkit,¹ these results can be used to directly configure a software layer interconnecting the data access layers of different systems with heterogeneous data interpretations. It should be pointed out that the data mediation layer is not an isolated technical solution to gain interoperability between different

¹ Respective Toolkits have been developed and applied by the authors in German harmonisation projects.

information systems, but is integrated in an overall data management process. The following figure illustrates the concept. The data management agency harmonizes the heterogeneous data models of the legacy systems. The results are used to configure the data mediation layer that enables the systems to interchange information based on the common shared data model.

To this end, data mediation can be interpreted to be a strategy to implement data interoperability through data transformation mechanisms. These promote common data interchange by mediating individual data representations into a semantic equivalent shared data model representation, i.e., SDEs, and vice versa. The objective is to enable separate systems and system components, which have an overlap of interest, to interchange or share data in a common data representation independent from any system implementation.

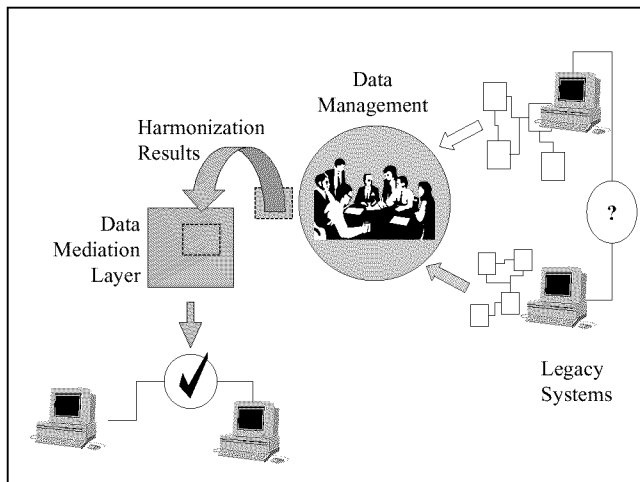


Fig. 1: Data Harmonization in the Integration Process

The data mediation implementation described in this document favors a software framework which may be linked as an additional software layer to existing systems and system components. This framework is a common platform to migrate existing systems and system components and integrate future ones into a shared data model based interconnection network.

It is characterized by the observation that integrating different data representations (schemas) as a prerequisite to build a database system federation, is also a prerequisite for data transformation. Data mediation then is almost equivalent to navigate through such an integrated schema.

The data mediation approach is derived from database federation techniques, thereby, extending these techniques. The database federation approach enables global applications to access different database systems transparently while interacting with a common (global) database schema.

The different underlying database schemas are integrated using a five level schema approach (component, local,

export, global and external schema) as shown in the next figure.²

The data mediation approach extends the database federation approach by harmonizing any data representation with an object-oriented shared data model (e.g., ATCCIS) representation using the same integration levels. Data sources are no longer restricted to database systems. Any software component which produces and consumes data is considered as a “data storage medium”. With this approach the framework is a common shell for any system component summarizing these aspects in a common software platform architecture.

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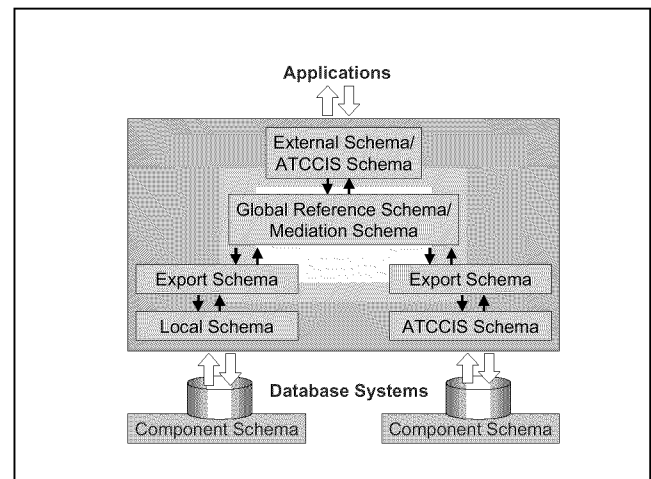


Fig. 2: Five-Level-Schema for Schema Integration

The actual approach implements the framework for collaborative processing as a virtual object-oriented database system, based on a mediation schema (built from an individual data representation and the ATCCIS representation), where the location of the data is completely transparent to the considered systems and system components. An individual system and system component may interact with the data mediation framework using a standard object-oriented database interface. The corresponding data may come from a local database system, from another system component or from a remote system which is interconnected to the current

² As has been pointed out, we recommend to use ATCCIS as the shared data model, thus, the ATCCIS schema is referenced in the respective figures.

system. Existing systems and system components, linked to the data mediation framework, become encapsulated and provide an common data representation.

Therefore the described framework approach not only permits to build system federations on top of heterogeneous system components and systems but also decouples components of large-scale systems to enable these components to evolve independently.

The approach given in this paper enables any system component and any system with an individual data representation to be represented by a shared data model representation. This, however, requires to first harmonize individual data representations with the agreed standard schema, which has to be done by the system independent data management agency described in the former section.

From an architectural point of view, the framework is divided into a common mediation kernel and multiple interconnection cartridges as shown in figure 3. These two architecture element types can be defined as follows:

- **Common Mediation Kernel.**

The mediation kernel manages the object-oriented mediation schema and provides services to navigate from an individual system or system component schema to an standardized schema (e.g., ATCCIS) and vice versa.

- **Interconnection cartridges.**

The interconnection cartridges are customized to support interconnection to applications and multiple database systems, and communication middleware products such as the Common Object Request Broker Architecture (CORBA) or the Runtime Infrastructure (RTI).³ For ATCCIS-based database replication, the ATCCIS replication mechanism (ARM) is adopted.

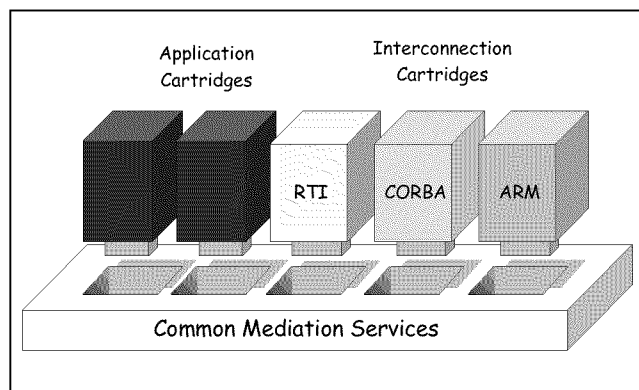


Fig 3: Interconnection Cartridges

³ The RTI is defined within the High Level Architecture (HLA) as one element of the Common Technical Framework (CTF) being the standard for interoperable simulation systems [NATO, 1998].

This finally reflects the design goals of the data mediation framework as an open and flexible add-on to functionally enrich existing communication middleware architectures like CORBA or the RTI, enabling a general approach for systems interconnection.

Federated Solutions of Heterogeneous Systems

The information techniques and management procedures having been described so far enables a new way of C3I system development.

As a first step, federations of heterogeneous information systems can be build. In order to do so, the information to be interchanged while an ongoing operation has to be specified using the agreed common shared data model. The next step is the harmonization of the exterior data view of the respective participating systems.

Using the appropriate toolkit, a software layer can be implemented, that enables the respective system to send and receive information using standardized data elements. Thus, the needed functionality can be reached by coupling different systems together in a loose way.

In the operational context, this means that the different partners within an alliance can use there own C3I systems for all functions that are supported and other systems for the rest. If, e.g., an additional communications server is needed, this one can be coupled with the rest of the federation using standardized data elements. As long as the information exchange requirements are within the scope of the external data view of a system, they can be fulfilled.

This is not only true for military information systems, but also for IT support of humanitarian relief organizations (e.g., Red Cross), governmental or non-governmental organizations, and every potential partner. Thus, the framework enables interoperability on the semantic information level between systems.

Next step should be the use of the ideas for intra-operability also, i.e., different applications supporting the warfighter by offering a special required functionality can be integrated into a new information system that can be adapted to the needs of a given operation. If an additional functionality is needed, the supporting application can be enriched with the data mediation software layer. Being then able to exchange information using SDEs, integration by respective cartridges is easy.

Finally, using these ideas consequently, the differences between inter- and intra-operability vanish. It doesn't matter any longer whether a needed function is implemented by the own system or an allied one, as the techniques bringing all applications together in the heterogeneous federation are equal for systems and applications.

The following figure exemplifies this. The framework for collaborative information processing can be used to couple the legacy systems A and B, hence coupling the respective comprised functionality, as well as to couple new applications to legacy systems or building new systems comprising only new applications.

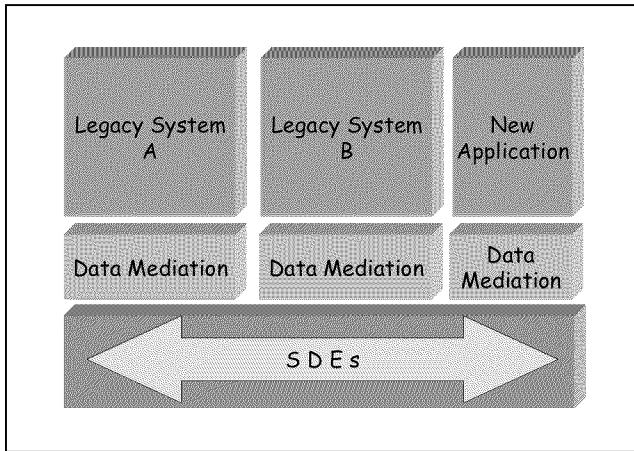


Fig 4: Intra- and Inter-Operability

To summarize these ideas: The intelligent use of standards is leading to synergy out of heterogeneity. Standards are not equalizers but reference concepts to be used to reach a common understanding of what's going on. Thus, participating allies within an operation do not have to change their systems, and it is not necessary to build a new system for every type of operation, but adaptable and configurable open and extendable solutions comprising reusable components become possible. On the long term, a library of functionality will become available to be used to couple together exactly the type of information system that is needed for a given operation. This can be even done "on the fly", i.e., from the home nations during an ongoing operation.

The Next Generation of IT Systems

There still may be the opinion that all of this becomes obsolete with the next generation of IT systems to support the warfighter. The authors want to point out that this will definitely not be the case. The need for data harmonization, data management, and data administration will not vanish, even if the next IT system generation comprises common data distribution and communication facilities for a set of common functions and applications. Looking, e.g., at the architecture worked out within the Defense Information Infrastructure (DII) Common Operating Environment (COE), all applications are capsulated and integrated into the new system. No application has to deal any longer with external data consistency, storage of data, transmitting data, etc. All this is done by global common functions of the DII COE.

However, there is still the need of data translation between the functional applications and the core data. Again, the

ideas of data mediation can be introduced to bridge the gap of semantic interpretation between the application and the core data. In addition, the requirements having to be fulfilled by the core data model are quite the same as having been mentioned before:

- All data needed by any application has to be stored.
- The integration of applications should leave the already stored data as it is.
- The introduction of new data and data types should be possible in order to fulfil all information exchange requirements.

Therefore, the idea is obvious to use the same information structures having been developed to support the data management for operational systems as the core data model also. The NATO C3 Data Model [NATO 1997] uses the principle of properties and propertyed concepts being only loosely coupled within the data model also. Taking this idea further and fusing it with the advantages of the ATCCIS data model and the insights gained from the experiences with data management leads to a new concept of operational data models that are able to be configured within the operation without any shut-down or re-boot of the system. New applications can be introduced, new data interpretations can be down-loaded during the operational use. To do so, the same mechanisms having been introduced to configure the data mediation facilities are now used to configure the operational data base.

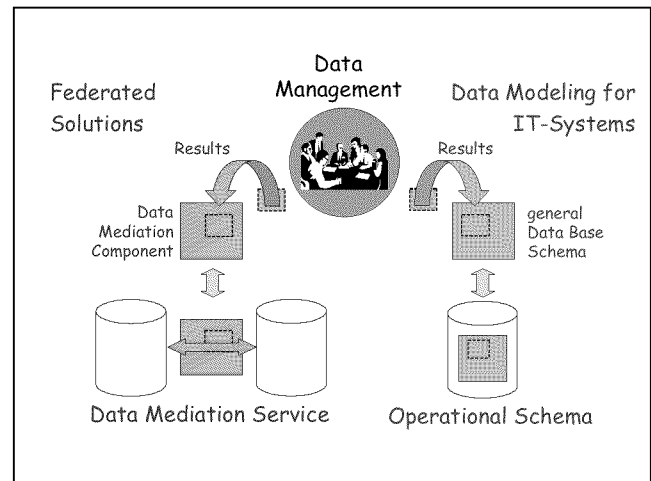


Fig 5: Configuring Operational Schemas

To summarize this: The authors have found a way to meet the information needs of the military user whenever they are defined, may it be in advance of an operation, in the preparation phase, or even when the system already is in use. Therefore, new applications – be they specially developed, brought in by partners or allies, or being commercial off the shelf products – can be integrated at any time within bringing the system back to the industry.

The UK has already made positive experiences with a very similar approach, and Germany is making first efforts to

introduce this new data modeling technology into their new operational systems.

Conclusions

The ideas of CPC are supposed to have a revolutionary effect on the Internet market enabling heterogeneous institutions and systems to develop systems with the consumer in the loop in a very efficient way. The underlying new technologies can be used also for collaborative information processing in military operations.

Kernel idea is the definition and use of a common shared data model for information exchange. This idea is not new to the military community. The SHADE [DoD, 1996] is a strategy to promote systems interoperability through a global view on the data of the battlespace. The SHADE's technical focus and priorities are driven by near term systems' integration, migration and interoperability requirements. Its main conceptual features address data interoperability for any federations of system components and systems in general, and thus, also provide an adequate approach towards the interconnection of C3I systems. Furthermore, in this paper, the necessity of an overall data management organization to effectively manage standard data as an operational asset has been stressed.

A framework for collaborative information processing as a common software platform, to meet the migration requirements of existing system components and systems, has been introduced. It implements standard data and mappings and allow users to access and interchange *as-is* data without knowing information about the common, standard data representation. On a mid term, the technique of data mediation will improve the migration of legacy systems in a cost efficient way.

It should be pointed out that only if all three columns of shared solutions are supported, this will finally lead to the desired success. These three prerequisites are:

1. A system independent data management agency has to be responsible for the standardized data elements and the common shared data model as well as the validation of the harmonization results of mapping legacy data to respective SDEs.
2. The toolkit family used by the data management agency and other people doing harmonization must be able to export the mapping results in a form readable to the framework for collaborative information processing.
3. All systems and applications must be integrated using the additional data mediation layer as well as the framework for collaborative information processing.

This leads to real federated solutions as a new C3I development paradigm meeting the new requirements emerging from joint and combined operations including operations other than war.

The ideas of data management are not to become obsolete when a single common system – e.g., the next generation of the Global Command and Control System (GCCS) or similar solutions resulting from the DII COE efforts – are introduced as one common systems to be used by all military services and/or all nations. It becomes even essential to ensure the meeting of user requirements for flexible IT support even in unpredictable operations by flexible and configurable core data capabilities. In this sense, the data management would offer the tools and procedures to enable the operational schema to support every function and application with the data it needs in the form it needs the information.

To conclude this paper, the last recent events concerning data administration and management activities in NATO should be given. Actually, ATCCIS is prepared to become the NATO Standard (STANAG) ADatP-32 [NATO, 2000]. In order to do so, in February 2000, the NATO Information Systems Sub-Committee (ISSC) tasked the NATO Data Administration Group (NDAG) to use ATCCIS as the reference model for the NATO Corporate Data Model (NATO CorpDM). Until the end of this year, these efforts are planned to lead to the first joint version of the NATO Corporate Data Model based on the ideas presented in this paper.

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Contact

E-mail: sk@dm-forum.org
at@dm-forum.org

(Dr. Stefan Krusche)
 (Dr. Andreas Tolk)

URL: www.dm-forum.org

Mail: IABG
 Einsteinstr. 20
 85521 Ottobrunn
 Germany